POOR QUALITY

PATENT SPECIFICATION

DRAWINGS ATTACHED

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Int. Cl.: —**F 02 c 7/26**

COMPLETE SPECIFICATION

Improvements in or relating to Gas Turbine Engines

We, ROLLS-ROYCE LIMITED, a British company of Nightingale Road, Derby, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to starting apparatus for gas turbine engines.

According to the present invention, there is provided a gas turbine engine having two relatively rotatable members at least one of which is drivingly connected to, or forms part of, a compressor of the engine, and starting apparatus comprising an induction motor of which the energisable part is secured to one of the members and the other part comprises an electrically continuous unwound metal member and is secured to, or forms at least part of, the other member.

By the term "unwound" it is to be understood that the metal member is not provided with coil windings or with conductor bars connected to form a winding as in motors of the squirrel-cage type.

Preferably, one of the members forms part of fixed structure of the engine.

In a preferred embodiment of the invention, the energisable part of the induction motor is secured to the member which forms part of the fixed structure of the engine.

Said other part of the induction motor may comprise a disc coaxially secured to a compressor shaft of the engine, or an axially extending annular strip member coaxial with a compressor rotor of the engine and bonded or otherwise suitably secured to a substantially axially extending part of the compressor rotor, or a radially extending annular strip member coaxial with and bonded or otherwise suitably secured to a compressor rotor disc of the engine.

Where said other part of the induction motor takes one of the forms described in the preceding paragraph, the energisable part of the induction motor may be arranged, where appropriate, to co-operate either with one surface only of said other part or with oppositely disposed surfaces on said other part.

Preferably, the energisable part of the induction motor is annular in shape.

Said other part of the induction motor is preferably made from aluminium or an aluminium-base alloy.

The gas turbine engine may also be provided with a supply of excitation current connectable to the energisable part of the induction motor, whereby, at the normal operating speed of the compressor to which the induction motor is drivingly connected, the induction motor is adapted to operate as an electrical generator.

Where the gas turbine engine has a plurality of compressors, the starting apparatus is preferably drivingly connected to, or adapted to form part of, the high pressure compressor of the engine.

The invention will now be particularly described, by way of non-limitative example only, with reference to the accompanying drawings, in which:—

Figure 1 is a diagrammatic part-section of a gas turbine engine provided with starting apparatus in accordance with the invention; and

Figures 2 to 4 are diagrammatic part-sections of alternative embodiments of starting apparatus in accordance with the invention,

In Figure 1 there is shown a gas turbine engine 10 comprising, in flow series, a low

pressure compressor 12 and a high pressure compressor 14. Connected in flow series with the high pressure compressor 14 are combustion equipment (not shown), a high pressure turbine (not shown) which is drivingly connected to the high pressure compressor 14 by a shaft 16, a low pressure turbine (not shown) which is drivingly connected to the low pressure compressor 12 by a shaft 18 coaxial with the shaft 16, and a jet pipe terminating in a propulsion nozzle (not shown). An annular by-pass duct 20, which surrounds and is coaxial with the high pressure compressor 14, the combustion equipment and the turbines, extends between the downstream end of the low pressure compressor 12 and the jet pipe.

The high pressure compressor 14 comprises a substantially cylindrical casing 21 which is coaxial with the shaft 16 and contains a plurality of stator stages 22 alternating with a plurality of rotor stages 24. Each stator stage 22 includes a plurality of radially extending stator blades 26 secured at their outer ends to the casing 21, the inner ends of the stator blades of the first stator stage being adapted to support a bearing 28 in which the shaft 16 is rotatably mounted. The stator stages 22 thus constitute part of the fixed structure of the engine 10. Each rotor stage 24 comprises a titanium rotor disc 30 coaxially secured to the shaft 16 and having a flattened rim portion 32 to which a plurality of radially outwardly extending rotor blades 34 are attached.

The engine 10 is provided with starting apparatus comprising an induction motor 40 which is drivingly connected to the high pressure compressor 14.

The induction motor 40 is constituted by an annular energisable part 42 which is secured to the radially inner ends of the stator blades 26 of the second stator stage 22, so as to be coaxial with the shaft 18, and a drivable part 44 which is relatively rotatable with respect to the energisable part 42 and takes the form of an aluminium or aluminium-base alloy disc 45 coaxially secured to the shaft 16. The energizable part 42 of the induction motor 40 comprises an annular magnet structure 46 which has a claw-shaped cross-section in an axial plane, opposite limbs 48 of the claws being radially inwardly extending and arranged to embrace the entire periphery 49 of the disc 45 and to support respective sets of laminated pole pieces 50. The pole pieces 50 extend parallel to the axis of the disc 45 to within a small distance (typically 0.025 inches) of its oppositely disposed surfaces 51, and carry windings 52 which are connected to a supply of multi-phase alternating current (not shown).

In operation, the windings 52 are energised by the supply of multi-phase alternating current, thus producing a cyclically varying magnetic field between the pole pieces 50. The magnetic field in turn induces eddy currents in the disc 45 (which currents are mainly confined to its periphery 49), thus causing the disc 45 to rotate with respect to the energisable part 42 of the induction motor 40. The disc 45 therefore drives the shaft 16, causing the high pressure compressor 14 and its associated high pressure turbine to rotate.

When the high pressure compressor 14 reaches a predetermined rotational speed, fuel is supplied to, and ignited in, the combustion equipment by means not shown. The gaseous combustion products from the combustion equipment act upon the high pressure turbine to accelerate it (and therefore the high pressure compressor 14) in the same rotational direction as that produced by the induction motor 40, while also causing the low pressure turbine and the low pressure compressor 12 to start to rotate. When the rotational speeds of the compressors 12, 14 are sufficiently high for the operation of the engine 10 to be self sustaining, the starting of the engine 10 is complete and the windings 52 are de-energised.

In the alternative embodiment of the invention shown in Figure 2, the induction motor 40 (indicated by solid lines) is constituted as before by the annular energisable part 42 which is secured to the radially inner ends of a stator stage (not shown) as hereinbefore described, and the drivable part 44 which is relatively rotatable with respect to the energisable part 42. However, the drivable part 44 takes the form of a radially extending annular strip member 60 of aluminium or aluminium-base alloy which is coaxial with the rotor diisc 30 and bonded or otherwise suitably secured to one face 62 thereof, while the annular magnet structure 46 of the energisable part 42 has only a single radially inwardly extending annular limb portion 64 which supports one set of laminated pole pieces 66. The pole pieces 66 extend parallel to the axis of the annular strip member 60 and to within a small distance of its surface 48.

If desired, a further induction motor 40a (indicated by dotted lines) having its annular strip member 60a bonded or otherwise suitably secured to the other face 62a of the rotor disc 30, may be provided, thus reducing the power output required from each induction motor 40, 40a.

In the Figure 3 embodiment of the invention, the drivable part 44 of the induction motor 40 takes the form of an axially extending annular strip member 70 of aluminium or aluminium-base alloy which is coaxial with the rotor disc 30 and bonded or otherwise suitably secured to the radially inner surface 72 of the substantially axially extending part of the rotor disc 30 constituted by the flattened rim portion 32 thereof, while the annular magnet structure 46 of the energisable part

42 is provided with a single axially extending annular limb portion 74 supporting one set of laminated pole pieces 76 which extend radially of the annular strip member 70 to within a small distance of its surface 78.

Figure 4 shows the induction motor 40 drivingly connected to a drum-type compressor rotor 80: in this embodiment of the invention the drivable part 44 takes the form of an axially extending annular strip member 82 of aluminium or aluminium-base alloy coaxial with the rotor 80 and bonded or otherwise suitably secured at one of its axial extremities to a substantially axially projecting internal part 84 of the rotor 80, while the annular magnet structure 46 of the energisable part 42 has a claw-shaped cross-section in an axial plane, opposite limbs 86 of the claws being axially extending and arranged to embrace the annular strip member 82. The limbs 86 support respective sets of laminated pole pieces 88 which extend radially of the annular strip member 82 to within a small distance of ints radially inner and outer opposite surfaces 90.

The operation of the embodiments of the invention shown in Figures 2 to 4 is analogous to the operation of the embodiment shown in Figure 1 and will not, therefore, be further described.

It will be appreciated that the design of the energisable part 42 of the induction motor 40 is dependent, *inter alia*, upon the dimensions (particularly diameter) of the space available in the engine 10 for its location and on the torque necessary to start the engine 10.

Thus in cases where the available diameter is comparatively large and/or the starting torque required is comparatively low, the energisable part 42 would be part annular rather than a complete annulus, whereas where the available diameter is comparatively small and/or the starting torque required is comparatively high, a plurality of co-operating induction motors 40 each having its energisable part in the form of a complete annulus may be employed, as indicated in Figure 2.

It will further be appreciated that since the energisable part 42 is energised only for comparatively short periods (typically 30 seconds) a considerably high current that that permissible for continuous operation may be permitted to flow therein.

The drivable part 44 of the induction motor 40 should have a width, at right angles to the lines of magnetic flux from the energisable part 42, greater than the width occupied by the flux so as to intercept substantially all the flux. Typically the width of the drivable part 44 in the described embodiments of the invention should be such that it extends radially of the energisable part 42 at least 1½" on each side of the pole pieces thereof.

Any material having suitable electrical conductivity and mechanical strength may be used to make the drivable part 44: aluminium and aluminium-base alloys are preferred since they combine the desired electrical and mechanical properties with low weight. Thus were a gas turbine engine is provided with a compressor of which the rotor discs are made from aluminium or an aluminium-base alloy, it is not necessary to provide the induction motor 40 with separate drivable parts 44, since the rotor disc itself may be employed as the drivable part. This is most easily seen in relation to Figures 2 and 3, where the annular strip members 60, 60a and the annular strip member 70 respectively could be dispensed with entirely if the rotor disc 30 in either embodiment were made from aluminium or an alloy thereof. The objection to dispensing with the drivable part 44 in the described embodiments of the invention is that the rotor disc 30 is made from titanium, which has a comparatively low electrical conductivity and would therefore be subject to severe overheating due to the eddy currents induced therein by the energisable part 42.

It is to be understood that the positions of the energisable part and the drivable part can be interchanged: thus the energisable part can be secured to a rotatable part of the engine while the drivable part can be secured to fixed structure. Also, it is possible to drivingly connect the induction motor within a compressor-driving turbine of an engine, or between contra-rotating compressors of an engine.

Finally, it will be appreciated that the use of starting apparatus in accordance with the invention avoids the necessity for complex and heavy reduction gearboxes which must usually be provided when conventional electric starter motors are used to start gas turbine engines.

WHAT WE CLAIM IS:—

1. A gas turbine engine having two relatively rotatable members at least one of which is drivingly connected to, or forms part of, a compressor of the engine, and starting apparatus comprising an induction motor of which the energisable part is secured to one of the members and the other part comprises an electrically continuous unwound metal member and is secured to, or forms at least part of, the other member.

2. A gas turbine engine as claimed in claim 1, wherein one of the members forms part of fixed structure of the engine.

3. A gas turbine engine as claimed in claim 2, wherein the energisable part of the induction motor is secured to the member which forms part of the fixed structure of the engine.

4. A gas turbine engine as claimed in any of claims 1 to 3, wherein said other part of the induction motor comprises a disc co-

axially secured to a compressor shaft of the engine.

5. A gas turbine engine as claimed in any of claims 1 to 3, wherein said other part of the induction motor comprises an axially extending annular strip member coaxial with a compressor rotor of the engine and bonded or otherwise suitably secured to a substantially axially extending part of the compressor rotor.

6. A gas turbine engine as claimed in any of claims 1 to 3, wherein said other part of the induction motor comprises a radially extending annular strip member coaxial with and bonded or otherwise suitably secured to a compressor rotor disc of the engine.

7. A gas turbine engine as claimed in any preceding claim, wherein the energisable part of the induction motor is arranged to co-operate with one surface only of said other part.

8. A gas turbine engine as claimed in claim 4 or claim 5, wherein the energisable part of the induction motor is arranged to co-operate with oppositely disposed surfaces on said other part.

9. A gas turbine engine as claimed in any preceding claim, wherein the energisable part of the induction motor is annular in shape.

10. A gas turbine engine as claimed in any preceding claim, wherein said other part of the induction motor is made from aluminium or an aluminium-base alloy.

11. A gas turbine engine as claimed in any preceding claim, including a supply of excitation current connectable to the energisable part of the induction motor, whereby, at the normal operating speed of the compressor to which the induction motor is drivingly connected, the induction motor is adapted to operate as an electrical generator.

12. A gas turbine engine as claimed in any preceding claim, including a plurality of compressors in flow series, the starting apparatus being drivingly connected to or adapted to form part of the high pressure compressor of the engine.

13. A gas turbine engine substantially as herein described with reference to the accompanying drawings.

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1147730 COMPLETE SPECIFICATION

3 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

Fig 1

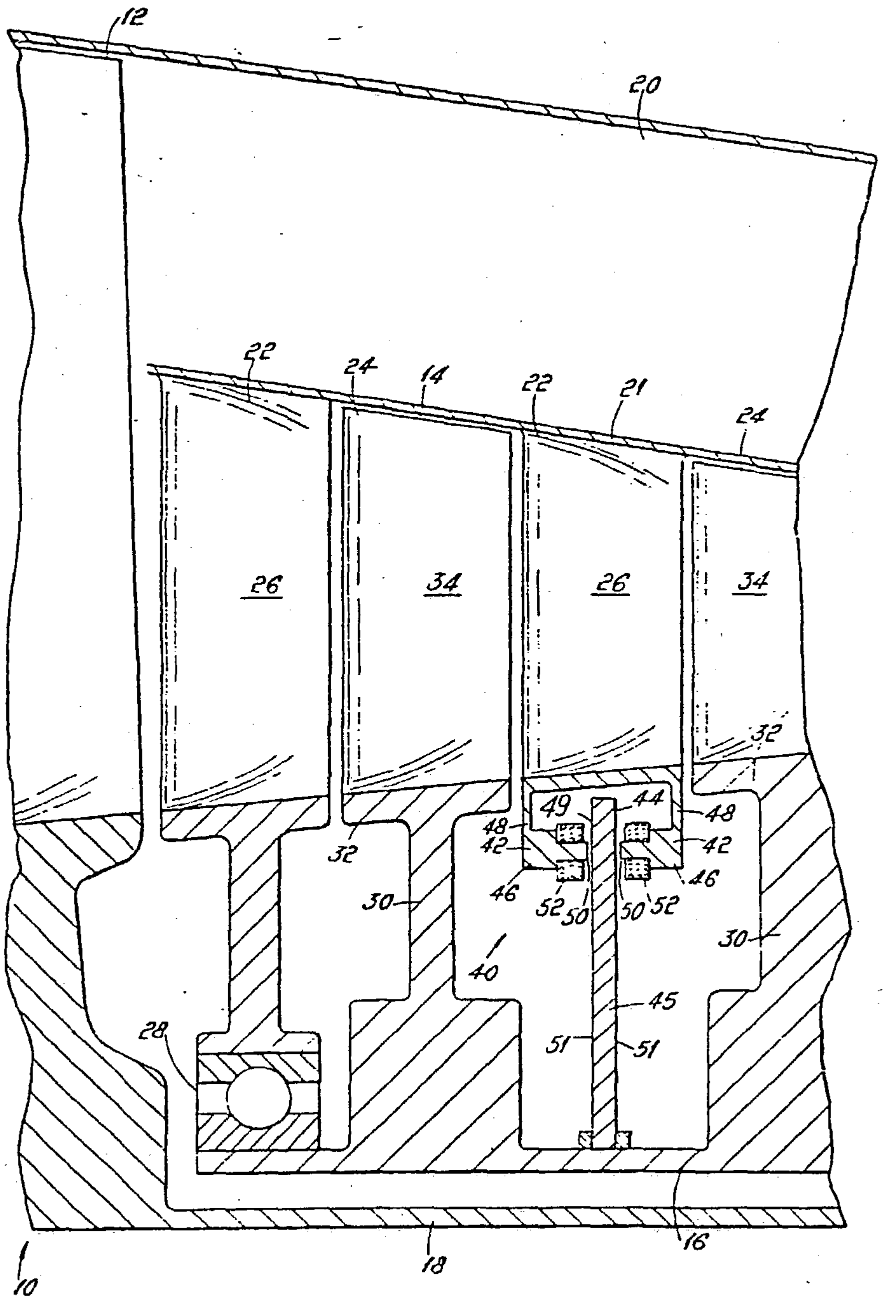
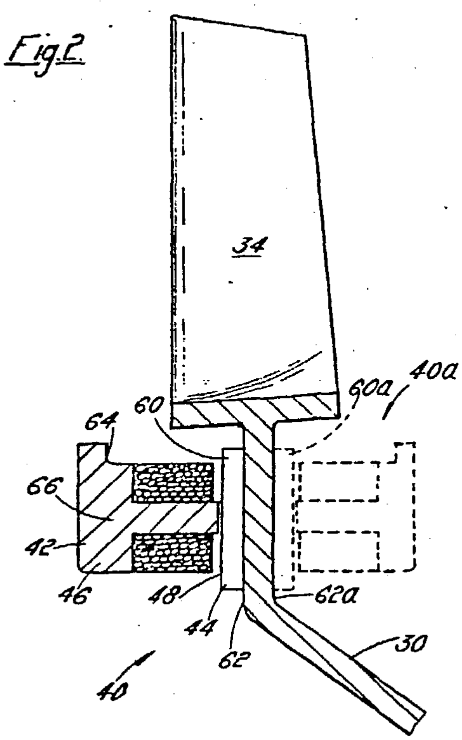


Fig.2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40a
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62a
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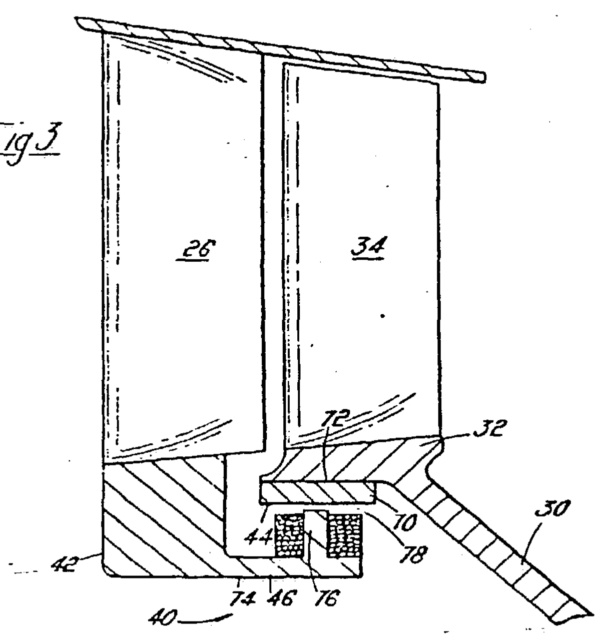
Fig 3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1147730 COMPLETE SPECIFICATION

3 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheets 2 & 3

Fig. 4.